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OBSERVATIONS ON AN ATTACK BY SHOT-HOLE BORER ON TEA

C. H. GADD

INTRODUCTION

That Shot-hole borer (*Xyleborus fornicatus* Eichoff, *fornicatior* Eggers) does not attack tea bushes to any appreciable extent during their first year from pruning has been amply demonstrated by Jepson. Concerning an experiment carried out on Sarnia Estate, Badulla, in a field which was pruned in August, 1920, he stated that it was not until February, 1922, (*i.e.*, 18 months after pruning) that the attack by shot-hole borer, though still small, was sufficient for a comparison to be made between the various plots.[2] In a second experiment on the same estate, the field being pruned in August/September, 1920, it was not until May, 1922, (*i.e.*, 20 months after pruning) that the attack was sufficiently advanced to be measurable.[3] His third experiment was carried out on New Peradeniya Estate, New Peradeniya. There, the field was pruned in July, 1923, but it was not until September, 1924, (*i.e.*, 14 months after pruning) that "the attack by borer was considered sufficiently severe to warrant the carrying out of a detailed examination in the field." [4]

His data, however, do not allow of a detailed study of the attacks which occurred during the second year of pruning. More recently, observations have been made concerning the incidence of shot-hole borer during a period of increasing attack, and the data then collected is here used for a study of that attack.

METHOD

The experiment was carried out on Gonakelle Estate, Passara, at an elevation of 3,500 feet. An area in a field which had been pruned in November/December, 1938, was divided into 6 plots, each being approximately one-fifteenth of an acre. Three of the plots were normally plucked and the other three were plucked harder. The experimental plucking started on 12th May, 1939.

At 3-week intervals between February 7th and November 29th, 1940, ten bushes selected at random in each plot were clean pruned. All the prunings of the 60 bushes were carried to the laboratory and there examined for shot-hole borer galleries.

Borer galleries can be classified as open or healed, according as the entrance is healed over or not. Newly healed galleries are comparatively easy to detect. Old 'heals' are sometimes only definitely disclosed by shaving away the surface until the obliterated gallery is revealed, or by splitting the branch longitudinally. Open gallery entrances, however, are unmistakable.

Galleries with open entrances, here termed *open* galleries, can after dissection be divided into those which are occupied by living beetles and those which are not. Open galleries have therefore been classified as *occupied* and *empty*. The empty galleries can again be sub-divided into those which have been vacated after a brood has been raised, and those which were abandoned before egg-laying started. These have been termed *vacated* and *abandoned* galleries respectively. There is no difficulty in distinguishing between an abandoned and a vacated gallery. The former is always much shorter than a normal gallery in which a brood is raised, and it gives the impression that the gallery has been occupied but for a short time. The presence of such galleries suggests that beetles after starting to bore may find conditions unsatisfactory and go elsewhere.

There are therefore four types of galleries — healed, vacated, abandoned and occupied. The first three contain no living occupants while the last-named does. The sum of the four different sorts gives the *total* galleries. Vacated and abandoned galleries together constitute what are here termed 'empty' galleries.

The numbers of galleries of all sorts found at each examination in the 60 bushes are given in Table I. The same information is given somewhat differently and in graphic form in Fig. 1.

The total numbers of galleries found at each examination are shown as small crosses in Fig. 1. It may be seen from Table I or Fig. 1 that the total number of galleries remained fairly constant until about the seventh examination on June 12th, but after that date the number steadily increased. Increases can often be expressed as interest, either simple or compound. If the increase in this case follows any interest law it obviously, from Fig. 1, is more closely allied to compound than to simple interest because the increases between examinations are not equal.

TABLE I

The number of Shot-hole borer galleries found in the prunings of 60 bushes. The bushes were previously pruned November/December, 1938.

Examination	Date 1940	Type of Gallery				
		Healed	Vacated	Abandoned	Occupied	Total
1	February 7th	31	16	1	8	56
2	,, 28th	19	7	2	4	32
3	March 19th	26	15	—	8	49
4	April 9th	30	12	1	20	63
5	May 1st	25	8	4	17	54
6	,, 23rd	32	4	2	32	70
7	June 12th	41	16	—	59	116
8	July 3rd	36	16	5	87	144
9	,, 24th	19	28	2	109	158
10	August 15th	29	45	16	171	261
11	September 5th	43	59	13	204	319
12	,, 24th	66	89	14	386	555
13	October 16th	100	187	40	461	788
14	November 6th	136	270	72	434	912
15	,, 29th	226	327	81	622	1,256

Calculations* have been made to determine what compound interest curve would best fit the observations made between May 23rd and November 29th inclusive (see Appendix Note A). That curve is drawn as the solid line in Fig. 1 marked A (Total), and it will be seen that the observed values agree fairly well with the theoretic values given by the curve. The curve shows how 53 galleries on May 1st would increase at a rate of 10.7 per cent per week, compound interest. At that rate of increase the number of galleries is doubled every 6.5 weeks.

Similarly, the number of healed galleries found at each examination is indicated by a small circle; and a compound interest curve which best fits the last six observations has been calculated (Appendix B) and is shown by the solid line C (Healed). This curve represents a rate of increase of 14.7 per cent. The number of healed galleries is consequently doubled every 4.7 weeks.

* Formulae and mathematical methods are relegated to an appendix as these will be of little interest to many readers.—C. H. G.

A third curve B is also shown in Fig. 1. This curve represents the rate of increase of healed *plus* empty galleries. The observed values are shown as small triangles. The curve represents a rate of increase of 14 per cent which is approximately equal to that found for healed galleries (Appendix C).

DISCUSSION

Before proceeding to make any deductions from the theoretic curves derived from the observed data, it is advisable first to ascertain what reliability can be placed on such conclusions. It is well known that two totally different formulae may, within a certain range of values, equally express the relationship between two variables. In this instance, compound interest formulae have been found to express tolerably well the rate of increase in the number of galleries within a certain range of observations. But there is no certainty that the same formulae will express equally well the rates of increase at other times. Consequently, any conclusion involving the use of a compound interest formula outside the period from which it has been calculated must be regarded with caution. Such conclusions can at best be merely tentative until confirmed by other observations, preferably direct observations.

CESSATION OF ATTACK

It will be evident that as the healed *plus* empty galleries are increasing at a more rapid rate than the total galleries, there will be a time when the empty *plus* healed galleries will equal the total galleries, if the two rates are maintained. Theoretically, that would occur about the middle of April, 1941, (Appendix D) when the total galleries would number 8,920 or 149 per bush. Then, as all the galleries would be either empty or healed there could be no occupied galleries from which beetles could emerge to continue the attack. In other words, the attack must cease by the middle of April in the third year.

No great importance can be attached to the actual number of galleries calculated, nor perhaps to the actual time. It will be sufficient to conclude that if the conditions ruling during the observed period continue, the attack must cease in the third year from pruning. If that is true, certain conditions must be operating all the time, even before November 29th, 1940, which ultimately stop the attack.

We must therefore first determine whether there is any evidence which supports the conclusion that shot-hole borer attack ceases during the third year. The only published data which throw any

light on this point are Jepson's.[3] His experiment was carried out on Sarnia Estate, Badulla, with 25 plots. The bushes had been pruned in August/September, 1920. At each examination, the galleries in 5 bushes from each plot, *i.e.*, 125 in all, were counted. The first examination was made in May, 1922, 20 months after pruning. After that date 3 other examinations were made at approximately 6-month intervals.

In Table II the information given in the first 7 columns has been obtained from Jepson's published data; that given in the last 3 columns has been obtained by simple calculation. It will be seen that between the first and second examinations there was an increase of 7,550 galleries; in the following six months the increase was only 2,251, and in the final period there appeared to be a decrease in the number of galleries.

TABLE II

Jepson's data regarding Shot-hole borer attack

Examination	Age from pruning months	No. of bushes	Number of galleries				% Occupied	No. occupied	
			Total	Open	Dissected	Occupied		Total	Per bush
1	20	625	10,774	6,320	625	513	82.08	5,188	8.3
2	26	625	18,324	8,227	625	311	49.76	4,094	6.6
3	32	625	20,575	2,979	625	374	59.84	1,783	2.8
4	38	625	16,680	2,872	625	364	58.24	1,673	2.7

That decrease is somewhat difficult to understand as a gallery once formed cannot disappear entirely. But the entrance may be healed and thereby become less obvious. Jepson's observations were made in the field and he has commented on the difficulty of determining accurately the number of healed galleries under those conditions. We may therefore assume that the short count of galleries was mainly, if not entirely, of healed galleries.

The counting of open galleries is less liable to error. Of these, the occupied galleries are the more important as it is from these galleries future attacks will be carried on. The occupied galleries were not counted separately, but from the fact that a number of open galleries were dissected and sorted into 'empty' and 'occupied' it is possible to estimate the percentage of the open galleries that were occupied. From that percentage and the number of open galleries found at each examination, it is possible to get an approximate estimate of the number of occupied galleries at each occasion. These estimates are shown in the last two columns of Table II as 'Total occupied galleries' and as 'Occupied galleries per bush.'

From these figures it will be seen that the number of occupied galleries decreased at each examination after the first, the greatest decrease occurring between the 26th and 32nd month, *i.e.*, in the 3rd year from pruning. The first examination was not made until 20 months from pruning because then only "the attack by borer was sufficiently advanced to provide information upon which calculations could be based." It is evident from the figures that it was made at the time when the attack had increased and was increasing rapidly, and probably had nearly reached its maximum. In the third year, the attack decreased until ultimately the low level of 2.8 occupied galleries per bush was all that could be found.

There is evidence from outside sources therefore, that shothole borer attack, though it may not cease entirely in the 3rd year from pruning, is very materially reduced; in fact, the number of occupied galleries found in the third year is less than one-third of the number found 20 months after pruning. We may therefore look with confidence for causes of the cessation of attack.

PERIODS OF OCCUPATION AND HEALING

From Fig. 1 it is possible to determine the theoretic values of the number of occupied, empty or healed galleries at any time by measuring vertically, using the vertical scale, the distance between the appropriate lines; it is also possible to measure the mean time of occupation and the mean time of healing by measuring horizontally the distance between the same lines, using the horizontal scale. For instance, on November 29th the date of the last observation, there were, theoretically, 223 healed galleries represented by the height of line C on that date; empty galleries numbered 450, and occupied galleries 628, represented by the vertical distance between lines B and C and between A and B respectively. The total is 1,301, represented by the vertical height of line A. The numbers actually found on that date, from Table I, were, healed 226, empty 408, and occupied 622, making a total of 1,256.

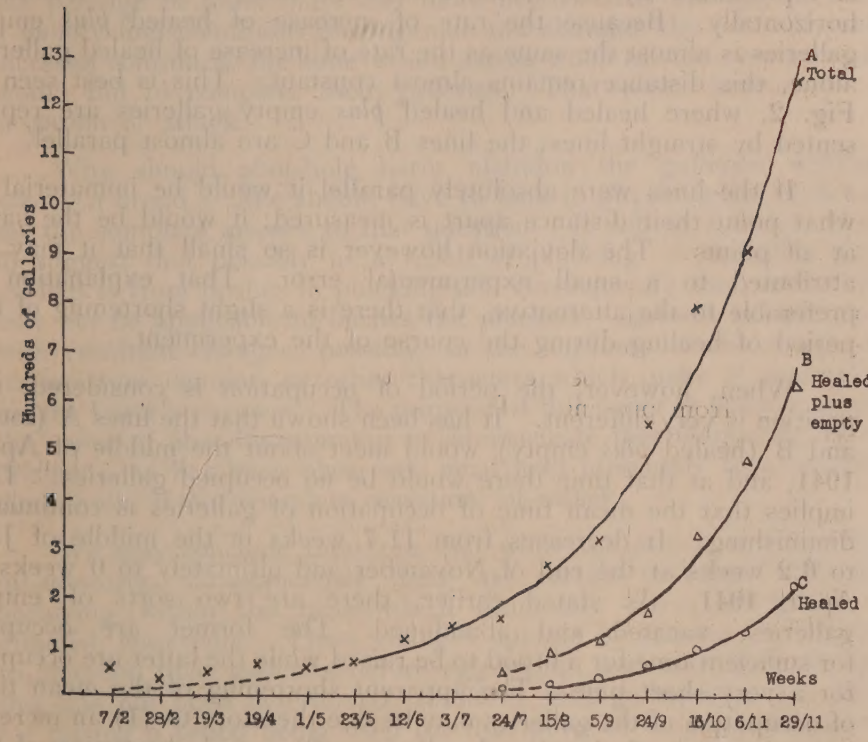

Fig. 1.—Graph showing actual and theoretic values for the number of galleries found in the prunings of 60 tea bushes. Data of Table I.

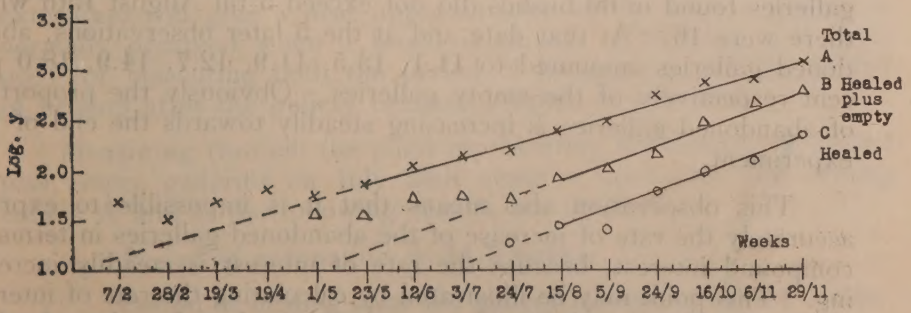

Fig. 2.—Straight lines fitted to Logarithms of Data of Table I.

The mean time taken for galleries to heal after being vacated is represented by the distance between lines B and C measured horizontally. Because the rate of increase of healed *plus* empty galleries is almost the same as the rate of increase of healed galleries alone, this distance remains almost constant. This is best seen in Fig. 2, where healed and healed *plus* empty galleries are represented by straight lines; the lines B and C are almost parallel.

If the lines were absolutely parallel it would be immaterial at what point their distance apart is measured; it would be the same at all points. The deviation however is so small that it may be attributed to a small experimental error. That explanation is preferable to the alternative, that there is a slight shortening of the period of healing during the course of the experiment.

When, however, the period of occupation is considered, the position is very different. It has been shown that the lines A (total) and B (healed *plus* empty) would meet about the middle of April, 1941, and at that time there would be no occupied galleries. This implies that the mean time of occupation of galleries is continually diminishing. It decreases from 11.7 weeks in the middle of July to 6.2 weeks at the end of November and ultimately to 0 weeks in April, 1941. As stated earlier, there are two sorts of empty galleries, vacated and abandoned. The former are occupied for sufficient time for a brood to be raised while the latter are occupied for a very short time. The apparent shortening of the mean time of occupation of the galleries may be due therefore to (1) an increasing proportion of abandoned galleries, (2) a real shortening of the time of occupation or to (3) a combination of both the above causes.

It will be seen from Table I that the number of abandoned galleries found in 60 bushes did not exceed 5 till August 15th when there were 16. At that date and at the 5 later observations, abandoned galleries amounted to 11.1, 13.5, 11.9, 12.7, 14.9, 18.0 per cent respectively of the empty galleries. Obviously the proportion of abandoned galleries is increasing steadily towards the end of the experiment.

This observation also means that it is impossible to express accurately the rate of increase of the abandoned galleries in terms of compound interest, because the rate of interest is steadily increasing. This point may be illustrated by calculating the rate of interest which best fits the observations made at the last 6 and at the last 4 examinations. For the last six observations the rate of increase was 13.6 per cent per week, whereas for the last 4 it was 19.5 per cent, a very appreciable increase.

Although it may not be possible here to express accurately the rate of increase of the abandoned galleries, it is obvious that, with the passage of time, more and more beetles after starting to bore a gallery find conditions uncongenial and abandon the job. If such increase continues, the time would arrive when all the new arrivals would fail to complete their galleries. That would amount to a cessation of attack.

Why should shot-hole borer abandon the galleries without raising a brood ? We should have to look to physiological evidence for the complete answer to that question. It will be sufficient here to suggest that possibly as a result of plucking — the data here studied is from bushes in plucking and consequently the conclusions may not be applicable to bushes not plucked — growth is restricted with resultant changes, possibly, in the hardness of the wood, or its moisture content, or other characters which make it unsuitable for the borer's purpose. The purpose of this paper is not to explain the cause of abandonment but to demonstrate that increasing abandonment, as has been observed, must lead ultimately to a marked diminution, if not complete cessation, of attack.

We may conclude therefore that while the attack is increasing in intensity, simultaneously there are certain undefined changes occurring within the bush which ultimately cause the attack to diminish materially. These changes operate by causing the beetles to abandon their galleries before egg-laying, and may also, though this has not been determined, result in such galleries as are used for raising a brood being used for that purpose for a shorter time.

From what has been said concerning the mean period of occupation, the length of that period will depend largely upon when it is measured. A measurement, taken before abandonment has become extensive, will give a near approximation to the time a gallery is normally occupied when a brood is raised. The basic date here used for measuring both the period of occupation and the period of healing after the gallery becomes empty, is July 24th.

Measuring through the point representing the number of healed *plus* empty galleries on July 24th along a horizontal line cutting curves A and C the following results are obtained :—

Period of occupation = 11.7 weeks.

Period of healing after the gallery is emptied = 8.4 weeks.

So far as the writer is aware, no previous attempt has been made to estimate the length of time a gallery is normally occupied by shot-hole borer beetles. When describing the life-history of the

beetle [1] the writer stated that eggs would completely disappear from the galleries after 64 days. He pointed out that that was an average figure but that it applied only to those galleries in which large numbers of eggs were laid. That figure, however, does allow an estimate of the period of occupation to be made. To it has to be added the larval period (15 days) and pupal period (7 days), and a few days also must be allowed for the adults to vacate the gallery (say 7 days). That would give a period of 93 days or 13 weeks as an estimate of a maximum period of occupation. In that light, an estimate of an average period of 11.7 weeks as obtained from the present data does not appear amiss.

The writer first made an estimate of the healing period in 1926 from Jepson's data.[4] The time measured on that occasion was from the time the gallery was formed (not vacated) till it was healed; consequently, it includes the time of occupation also. As now shown, much depends upon the time such a measurement is made. Concerning the control plots, the writer stated "the healing process may be taken as occupying 3.75 months, *i.e.*, the mean of 3.2 and 4.3 months." That estimate is shorter than the one made from the present data, which is 20 weeks or 5 months from the time the gallery is made till it is healed. The present data are more complete than Jepson's, and the writer is of the opinion that the present estimate is the more reliable. It must be pointed out, however, that Jepson's data were collected from a different district at a different elevation. Such differences may affect both the times of occupation and of healing.

King [5] has also published data concerning the healing of galleries. New entrance holes were observed for a period of 115 days. During that time 8 out of 49 were healed. The time taken to heal varied from 36 days to 103 with a mean of 77 days. It seems highly probable that most, if not all, of these galleries were abandoned, as the time measured includes the period of occupation as well as of healing. Unfortunately, no information is given concerning the galleries, but obviously, such times as 36 and 47 days are too short for both raising a brood and the healing of the gallery. 115 days is too short a time for an experiment of this nature where the *mean* time for healing *plus* occupation may, as determined here, be as much as 20 weeks or 140 days.

ORIGIN OF ATTACK

Fig. 1 shows that on June 12th, there were 73 galleries of all sorts (Total) by the theoretic curve as compared with 70 actually found. The curve has been continued backwards towards the beginning of the experiment as a broken line. The curve shows that if

the rate of increase had remained constant from the beginning of the experiment, only 14.7 galleries would be necessary to give rise to the curve studied (Appendix E). On February 7th when the first observation was made, 56 galleries were found, *i.e.*, nearly 4 times as many as the expected value. We may conclude, therefore, that the rate of increase between February 7th and June 12th was much less than that observed later, viz. 10.7 per cent.

If the increase had been 10.7 per cent, the 56 galleries on February 7th would have become 112 six and a half weeks later, and would have more than doubled again by June 12th, whereas we know that in the whole of that period the 56 galleries had only increased to 73. The attack therefore only became of real importance about June 12th, 18 months after pruning.

The 56 galleries found on February 7th were from 60 bushes, so they represent an average of 1 gallery per bush, or more correctly, the prunings from one bush. Those prunings represent the growth of 14 months. It will be evident therefore that if after pruning there is but one occupied gallery per bush, possibly much less, and that number can be maintained for 18 months till the new wood is suitable for attack, there will be sufficient beetles to ensure a severe attack later.

The fact that an extremely small number of occupied galleries left in a field after pruning is sufficient, without outside help, to give rise to a severe attack 18 months later, when the new wood is more suitable for the beetles, is not generally recognised. The requisite number is so very small that any attempt to reduce it seems futile.

That all attempts to eliminate shot-hole borer by mechanical methods such as trapping the insects, burning, banding, pruning of infested portions of plants, etc., have proved futile, is vouched for by Jepson.[3] He gives as the reason: "It is impossible without ruining the bush to eliminate all individuals present." He, however, goes on to say "The proper disposal of prunings is the only practical method whereby a large number of insects can be destroyed. This may be effected by the wholesale burning of the prunings immediately after pruning."

Those who have tried the effect of burning the prunings, and many have, have realised that it makes no material difference to later attack and the practice has rightly fallen into disuse. Periodically, the same idea is resurrected, judging from enquiries coming into the Institute. It may therefore be worth while to consider the matter further.

It must be admitted that the burning of prunings must destroy a large number of beetles. But it seems immaterial how many are destroyed so long as even very few remain established in the bushes. No special precautions were taken before the experiment under consideration was started. The prunings were not burnt nor buried. The beetles which may have emerged from the prunings did not find their way back into the pruned frames and breed there satisfactorily, else there would have been a much heavier attack later. More probably they died, or went to another field. The latter, as will be shown later, is unlikely. The whole of the data demonstrates beyond doubt that the attack observed originated from a very small number of beetles, and not from numerous galleries as would be expected if the frames were heavily infected. The burning of prunings therefore can do no good, and practical experience has amply confirmed that conclusion.

MORTALITY AFTER EMERGENCE

The total number of galleries has been shown to increase *only* at the rate of 10.7 per cent compound interest. Admittedly since at that rate the number of galleries is doubled every 6 weeks (approximately), astronomic numbers would be reached in a relatively short time if that rate could be maintained. Nevertheless, that rate of increase seems ridiculously small when conditions are favourable for the beetle, *i.e.*, when suitable wood is available.

The writer has shown elsewhere [1] that adult beetles emerge from occupied galleries at the rate of 0.26 per day and of these 27 per cent may be males. We may therefore put the emergence rate of female offspring as 0.19 per day or 19 in 100 days, *i.e.*, 1 every 5 days. As many as 34 adults may emerge from one gallery, but that number is rarely exceeded. If every female that emerged from one gallery established herself in the same bush, there would be 2 galleries after 5 days, 3 after 10 days and so on. This is an increase of more than 100 per cent per week simple interest. But it might be argued that the offspring do not stay in the same bush but fly elsewhere. They might fly to other bushes in the same field or in other fields. If their migration is restricted to the one field, as many beetles are likely to arrive at one particular bush from surrounding bushes as would leave that particular bush on flight. So the rate of increase should be the same. But suppose they fly to other fields. If the field they leave is a second year field and therefore most suitable for attack, unless they go to another second year field — when the exchange would be much the same as between bushes in the same field — they must fly either to fields in their first or third year from pruning. The wood in these fields is less

suitable for attack, as has been shown, and, as it seems very unlikely that the beetles would migrate to less suitable conditions, we must conclude that they most likely stay in the field in which they were raised.

There is, however, no information from direct observation by entomologists concerning the flight of the shot-hole borer apart from the fact that the beetle has wings and can fly. The suggestion is here put forward that they do not normally fly far but tend to remain near to the gallery in which they were raised.

This point does not materially affect the argument, but it will be evident that if the beetles fly from a heavily infested second year field they must die in large numbers because the wood in 1st and 3rd year fields is not eminently suitable for attack. All statistics available point to that conclusion. If they remain in the same field they must still die in very appreciable numbers, because the rate of increase observed in the number of galleries is very much less than what is expected from the rate of increase of female beetles.

We may therefore conclude, at least tentatively, that in addition to a heavy mortality within the galleries shown elsewhere [1] there is also a further large destruction of beetles after they emerge from the galleries. It would be interesting to compute more exactly the percentage of beetles which do not live long enough to form a gallery for themselves. On the present evidence, the destruction of beetles seems so great under existing conditions that it is likely to exceed what could be brought about by any parasite. In view of the demands made in certain quarters that the world should be combed for such a parasite the matter is worthy of further attention. No such parasite is known and, if the writer's views are further substantiated, it would appear a waste of time to look for one.

SUMMARY OF CONCLUSIONS

1. Attack by shot-hole borer does not become of economic importance during the first year from pruning.
2. The main period of attack is usually in the later half of the second year when the number of galleries may increase at a rate of 10.7 per cent compound interest.
3. The attack dies out during the third year.
4. Sufficient occupied galleries are left after pruning to ensure an attack during the next pruning cycle. The number of occupied galleries left need not exceed one per bush, and a much smaller number is all that is necessary.

5. Such measures as the burning of prunings can do little or nothing towards preventing a later attack.

6. The cessation of attack during the third year is due to factors which are operative and whose effects become increasingly deterrent as the attack progresses. These factors cause an increase in the percentage of beetles that abandon the galleries before egg-laying.

7. The effect of the same factors is shown by an apparent reduction in the mean time of occupation of the galleries by the beetles. When abandoned galleries are few the mean time of occupation is 11.7 weeks.

8. Healing is completed on the average 8.4 weeks after the gallery becomes empty.

More tentative conclusions include

9. The flight of the borer is probably very short. The proximity of heavily attacked tea is not a serious source of danger now. Every field liable to attack will always contain sufficient beetles to initiate the attack when the wood is suitable.

10. The heavy mortality amongst adult beetles, coupled with the mortality that occurs in the galleries, raises doubt that the presence of a parasite would materially improve matters.

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APPENDIX

A. The formula for a compound interest curve is $y = Ae^{rx}$ where y is the capital and accumulated interest, A the original capital, r the rate of increase and x the time during which the interest has accumulated, $e = 2.718$.

The same formula may be written as $\log y = a + bx$ where $a = \log.10^{A}$ and $b = r \log.10^{e}$. The graph for this formula is of course a straight line.

The procedure for determining the best compound interest curve was to fit the best straight line to the logarithms of the observations.[6] For total galleries that line is represented by log. $y = 1.724 + .046x$. x being the time in weeks counting from May 1st. Converting as above, A, the capital is 53 and r is found to be .107 or 10.7 per cent.

B. Only six observations have been used for the calculation of the curve to represent healed galleries as it is only from about July 24th that the logarithms of the observations approximate a straight line. This line is represented by the equation log. $y = 1.196 + .064x$ which gives A a value of 15.7 galleries on July 24th, and r a value of .147 or 14.7 per cent.

C. The healed *plus* empty gallery curve is calculated for the same period as for healed galleries. Log. $y = 1.736 + .061x$. This gives the increase rate of .140 or 14 per cent, and the number of galleries on July 24th as 54.5.

The graphs for the above three lines are given in Fig. 2 which also shows the data from which they were calculated. In Table III these and other equations are brought to a common zero time, viz. July 24th.

D. The time when the two lines meet is when $2.280. + .046x = 1.736 + .061x$; *i.e.*, when $x = 36.3$ weeks after July 24th.

E. The actual value has, of course, been calculated from the appropriate equation.

TABLE III

The Values of a and b of the equation log. $y = a + bx$ with July 24th as zero time.

Type of gallery	a	b	A	r	Period used for calculation
Total	2.280	.046	190.5	.107	May 23rd-Nov. 29th, 1940
Healed	1.196	.064	15.7	.147	Aug. 15th-Nov. 29th, 1940.
Empty + Healed	1.736	.061	54.5	.140	do.
Vacant	1.463	.061	29.0	.140	do.
Abandoned	0.853	.059	7.1	.136	do.
do.	0.485	.085	3.1	.195	Sept. 24th-Nov. 29th, 1940

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THE POSSIBILITY OF EXTENDING *CINCHONA* CULTIVATION IN THE BRITISH EMPIRE*

SIR GEOFFREY EVANS

INTRODUCTION

The *Cinchona* plant is the base for the manufacture of quinine, which is still the most important specific for malaria, in spite of the advent of synthetic drugs, such as plasmoquene and atabrine. The former drug is not now in favour, as it is said to give rise to certain toxic effects. Atabrine is of German origin and is protected by patents. Its cost is high, and it is stated [1] that the cost of treating one malaria case with it would be 4.9s. as against 1s. for a similar treatment with quinine. In view of the fact that vast areas of the territories owing allegiance to the British Crown are subject to this scourge, it is remarkable that about 90 per cent of the quinine products consumed in the world to-day is produced in the Netherlands East Indies, and that only about 4 per cent is made in British countries. It has been estimated that there are some

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800 million people in the world to-day who suffer from malaria and that there are 2 million fatal cases annually. A large proportion of these casualties are British subjects. For example, the League of Nations Health Organization gives data showing that 100 million people in British India alone suffer from malaria, but only 8 to 10 million are treated annually, and in other tropical parts of the Empire conditions are much the same.

The increased consumption of quinine is largely a matter of price and, running concurrently, of efficient propaganda. With lower prices, a wider knowledge of the nature of the drug and efficient means of distribution, the consumption could undoubtedly be largely extended. Even at present the consumption figures are very considerable. Thus India alone consumes about 210,000 lb. of quinine per annum, of which 70,000 lb. are produced in that country and 140,000 lb. are made from Dutch East Indies bark. The real need for India is provision for 100 million sufferers, using 45 grains a year, which would require 600,000 lb. of quinine sulphate annually. In the Colonial Empire the latest figures, as shown by the imports, indicate a consumption of about 70,000 lb. per annum. Many of the smaller island Colonies, such as Fiji, Tonga, and some of the West Indian islands, do not suffer from malaria and do not, therefore, import quinine. Taking the others, the Eastern Group consumes nearly 47,000 lb., the chief importers being Ceylon (27,500 lb.), Malaya (15,000 lb.), and Mauritius (3,100 lb.) The East African Colonies absorb over 11,000 lb., Kenya, Tanganyika, and Uganda each taking between 2,500 and 3,000 lb. annually. The West African group absorbs only 7,190 lb , an amount which is obviously very much less than the potential demand. In all these Colonies the need for quinine is great, but the obstacle of price, which is greater than the average inhabitant can afford stands in the way of any immediate increase of consumption.

The whole question of malaria control was specially considered by the Health Organization of the League of Nations. The Special Malaria Sub-Committee of this body inquired into the possibility of utilizing the other alkaloids that are present in *Cinchona* bark in addition to quinine. The conclusion reached was that the stricken peoples of the world would benefit from the use of a cheap febrifuge consisting of mixed alkaloids, provided these conformed to legally defined standards. Totaquina was the result of these deliberations and it is a febrifuge standardized to contain 70 per cent of crystallizable alkaloids, of which 15 per cent is quinine. Either it may consist of the total alkaloids of low quinine-yielding species, such as *C. succirubra*, or it may be made from the high-yielding *C. ledgeriana* residues with the addition of sufficient quinine to bring it up to

specification. Medical tests, according to Field,[2] have proved satisfactory, although it is stated to be slightly less effective than quinine and is unsuitable for intramuscular injections. Here again the question of cost arises, and totaquina is not likely to displace quinine unless it is appreciably cheaper. Theoretically the extraction of total alkaloids from the bark is easier and cheaper than the separation of quinine alone, but prejudice is in favour of quinine, partly because of its more attractive colour and appearance. The price of bark is the real crux of the question, and this is largely controlled at the present time by one organization which holds a practical monopoly, namely, the Kina Bureau of Amsterdam. This controls the production of bark in the Netherlands East Indies, a region which, as has been stated above, provides not less than 90 per cent of the total world production at present. The supplies from the South American countries, which are the original home of the plant are now negligible.

CINCHONA AND EARLY HISTORY OF ITS CULTIVATION

The genus *Cinchona* is a native of the Andean region and grows in a wild state on the eastern afforested areas of that region, between latitudes 10°N. and 9°S., in the Republics of Peru and Bolivia. There are 65 species of the genus *Cinchona* listed in *Index Kewensis* and all are characterized by possessing bark containing the quinine alkaloids to a greater or less degree. The classification has presented some difficulty to botanists, owing to the ease with which the species hybridize with one another, so giving rise to different forms. There are, however, only four species which are, or have been, cultivated to any extent for their alkaloids. These are *C. ledgeriana* Moens ex Trimen, which is also known as *C. calisaya* Wedd. var. *ledgeriana* Howard, from which Ledger Bark is obtained; *C. succirubra* Pavon ex Klotzech, which produces Red Bark; *C. calisaya* Wedd., yielding Yellow Bark; and *C. officinalis* Linn., giving Crown Bark or Loxa. There are two hybrids which have been cultivated from time to time, namely, Ledger Hybrid (*ledgeriana* × *succirubra*) and C. (*robusta* × *officinalis* × *succirubra*). Nowadays practically all the *Cinchona* bark of commerce is obtained from *C. ledgeriana* and *C. succirubra*. In Java selected plants of *ledgeriana* have given higher percentages, and in fact the contents of quinine and alkaloids seem to vary somewhat according to variety and also to environment.

Cowan [3] gives the following average percentages of the three main species as grown in India:—

	Quinine	Other alkaloids	Total alkaloids
C. ledgeriana	5.49	3.03	8.52
C. officinalis	2.93	2.07	5.00
C. succirubra	1.40	4.85	6.25

Analyses of the bark indicate that *C. ledgeriana* is richer in quinine than any other species, but that *C. succirubra* possesses a high total content of alkaloids, particularly in cinchonidine. These facts are of great importance in connection with the establishment of the planting industry, as naturally efforts have been made to cultivate *ledgeriana* on account of its high quinine-content, in spite of the fact that it is more particular in its requirements and is less easy to grow than the other species.

The history of the introduction of the plant to cultivation throws considerable light on the present state of the industry. Prior to 1857 supplies of bark were obtained in limited quantity from the native home of the tree in Bolivia and Peru, hence its old name of Peruvian Bark. It had long been known as a fever-freeing drug, as in 1639 the Countess of Chinchon, wife of the Spanish Viceroy of Peru, was cured by a decoction of the bark. A hundred years later Linnaeus perpetuated the name of this lady by giving the genus the name *Cinchona*.

No real effort seems to have been made to cultivate the tree in the South American forests, or to maintain supplies by replanting, and as the demand for the drug increased, especially after 1820, when French chemists isolated the main alkaloid from the bark and quinine sulphate became the established specific, the importance of securing more abundant and regular supplies became evident. Between 1845 and 1848 Dr. H. A. Weddell investigated the natural occurrence of *Cinchona* trees in South America and described the species. He commented on the reckless clearing of the forests and pointed out that cultivation would have to be undertaken if supplies were to be maintained. Weddell's seed was planted in the Jardin des Plantes at Paris, and a few years later, one of these plants was taken to Java, supplemented later by importations of seed and plants from South America and by exchange from India. Stimulated by his report the East India Company decided to dispatch an expedition to South America to obtain seeds and, if possible, plants, and placed Mr. (later Sir) Clements Markham in charge. A brief account of his journey is given by Dr. George Smith.[4]

Markham succeeded in collecting 529 plants, together with a quantity of seed, chiefly of the *calisaya* variety from 'the Province of Caravaya' in Peru. He arrived at Southampton in 1860, and after transmitting a portion that were dying to Kew,[5] he proceeded with the remainder to the Nilgiri Mountains in Madras Presidency, and eventually 270 survived the passage of the Red Sea. Meanwhile seed had been dispatched to Kew where, under Treasury instructions, a forcing house had been erected. A large number of seedlings were raised there in 1860-1, young stocks grown, and competent gardeners recommended to take charge of the new plantations in India. At the same time seed was supplied to the West Indies and Ceylon. The plants thus collected appear to have been chiefly of the two species *succirubra* and *officinalis*, neither of which possesses a high quinine-content. The next step was the introduction into cultivation of *C. ledgeriana* in 1865. Charles Ledger was an explorer and merchant, and an interesting account by Holland [6] relates how his henchman managed to collect seed from fifty trees of the 'rojo' sort from the banks of the Mamore river in Bolivia. Ledger sent the seed to London, where it arrived in good condition, and asked his brother to sell it to the British Government. He was unable to do this and sold the greater part of the seed (about 13 lb.) to Mr. J. W. B. Money, who owned *Cinchona* plantations in India. The latter did not use the seed himself, but exchanged it for *C. succirubra* seed with McIvor, the head of the Government Cinchona Plantations in Madras, since this variety appeared to be well suited to Nilgiri conditions. Little care seems to have been taken with Ledger's seeds in Madras, and although about 60,000 seedlings were said to have been raised, they were allowed to die out because the policy at that time was to concentrate on *succirubra*. A small pinch of seed had meanwhile been obtained by G. A. Gammie, the Superintendent of Cinchona Plantations in Bengal, and 800 seedlings were raised. Partly because the species appeared to do better in the Himalaya foothills than in the Nilgiris, and partly also because the true value of the *Ledgeriana* species was better appreciated, it was multiplied rapidly and soon began to replace the inferior varieties in the Bengal plantations. Meanwhile Ledger had disposed of his remaining seed amounting to 1 lb. to the Dutch Government, who sent it to Java, where it came into the possession of the Director of Cinchona Cultivation, J. C. Moens, in 1865. The new species took kindly to the soil and climate of Cheribon and Preangar, where most of the *Cinchona* is still grown to this day. The value of the new introduction with its high quinine-content was at once realized, and the Dutch with their usual thoroughness immediately began a system of rational selection which has borne abundant results.

According to Kerbosch,[7] the planters in Java early formed the opinion that the large-scale production of *Cinchona* bark with a low quinine-content would have no economic future. Accordingly, when *Cinchona* plants were first introduced by Markham, Hasskarl, and Schuhkraft, the planters took little interest, since these species, mainly *officinalis* and *succirubra*, produced bark with a low quinine-content. There was a change in the situation in 1873, by which time the first consignment of bark with a high quinine-content was produced from the plants raised from the seed purchased from Ledger in 1865. Private enterprise then began to develop plantations on a large scale, more especially as the medical profession was advocating more and more strongly the use of the drug, with the result that the market strengthened and widened. Ceylon was at that time a keen competitor of Java, as the planters had been anxious to find a substitute for coffee, which was being destroyed by the fungus disease *Hemeleia vastatrix*, and had substituted *Cinchona* for it. The area planted to *Cinchona* in Ceylon jumped from 1,500 acres in 1873 to 64,000 acres in 1883, but by then over-production had taken place and the price of bark fell from 72 Dutch cents in 1880 to 7½ cents ten years later. The Ceylon bark with the low quinine-content was at a serious disadvantage with the Ledger bark produced in the Dutch East Indies, and the industry declined rapidly. The area in 1893 was only 5,000 acres, and the *Cinchona* trees were grubbed up to be replaced by the new plantation crop — tea — which was then coming into favour and was found to grow well under the same conditions as *Cinchona*. To-day the Ceylon industry is dead.

In India the position was in some ways similar to that in Ceylon, with the difference that Government-owned plantations were maintained in the Nilgiri Hills of Madras and in the north-east of Bengal on the Sikkim border. These two regions are still the centres for quinine production in India, but private enterprise has ceased and only the Government plantations remain. At the height of the boom in 1880 it was estimated that the Government and private plantations in the Nilgiris and other parts of southern India amounted to 5,800 acres, with a production of 400,000 lb. of dry bark per annum. The Government plantations at Munsong and Mungpoo in Bengal covered 2,400 acres and private plantations in Darjeeling another 1,800 acres, the former producing 400,000 and the latter 150,000 lb. of bark per annum. In Ceylon at the same time the corresponding figures were 33,500 acres and 1,000,000 lb. of bark, Java at that time possessing 7,500 acres and 450,000 lb. In all parts of India the slump in prices caused by over-production saw the elimination of private plantations during the next decade.

There were essential differences in the management of the Government plantations in Madras and Bengal. In Madras, the policy had been to grow *succirubra* and to a less extent *officinalis* and *robusta* — species possessing a much lower quinine-content than *ledgeriana*. The reasons for this policy were partly that these species were those first introduced at the time of Markham's successful expedition, and also because conditions of soil and climate seemed to suit them better than *ledgeriana*. In Bengal, on the other hand, the value of *ledgeriana*, on account of the high quinine-content of its bark, was realised from the time when the first small consignment of seed had been secured with so much difficulty, and efforts were largely concentrated on the problem of establishing this species, so that up to the present time by far the greater part of the area is still planted in *ledgeriana*.

Cinchona was also tried in the early days in many parts of the British Empire, and apart from Ceylon and India, experiments were carried out in Malaya, the Sudan, St. Helena, Jamaica, Trinidad, Mauritius, and parts of Australia and New Zealand. In most of these places climatic conditions proved to be unsuitable, but in Jamaica a small industry flourished during the boom period The area cultivated in 1880 was estimated at 800 acres and the production at 50,000 lb. of bark per annum, but the economic conditions that proved so fatal in Ceylon and India also applied to Jamaica, and the industry speedily declined, so that at the present time all that remains to perpetuate the attempt is the name "Cinchona" which is given to a pleasant old house which is situated high up in the Blue Mountains and the headquarters of an old experimental garden of the Department of Agriculture.

This record of failures in the British possessions is in marked contrast to the state of the industry in the Dutch East Indies where it continues to flourish today. It will be interesting to examine the reasons for this success and the methods by which difficulties have been met and overcome.

CAUSES OF SUCCESS OF THE DUTCH INDUSTRY

Kerbosch [7] mentions that the effect of the slump in prices during the 'eighties caused by over-production was felt for twenty years afterwards, and the price reached such a low level that many undertakings in Java could hardly work at a profit. In fact, there was a danger during this period that *Cinchona* cultivation might be abandoned in favour of another crop, as happened in Ceylon. The first real improvement came in 1913 when the producers in the East

Indies came to an agreement with the manufacturers of quinine whereby the supply and sale of bark was regulated to keep pace with the world's consumption. This arrangement probably saved the estates from financial ruin, but has not really prevented the possibility of over-production, for far more bark could be obtained by the normal working of the estates than is now allowed to be produced by the agreement. A rapid expansion in output could, therefore, become effective, if the position of the market warranted such action.

Mention has been made of the measure of co-operation maintained between the growers and the quinine manufacturers which was achieved through the Cinchona Agreement of 1913. The administration of the Cinchona Agreement lies with the Kina Bureau in Amsterdam, which is made up of representatives of both growers and quinine manufacturers. Government influence is of importance, as about 10 per cent of the production of bark comes from Government-controlled plantations. Since 1934 bark production has been further controlled by the introduction of an export quota system, and Government decrees the amount of bark that shall be exported annually Thus, in 1936 the export quota was fixed at 1,646,851 lb. (expressed as quinine sulphate equivalent), but in order to meet the world's heavy demand the quota was increased in November by another 157,630 lb. The figures for 1937, 1938 and 1939 have been progressively lower. The producers of bark have benefited greatly by this restriction scheme, which was extended for another ten years on January 1, 1937. The feasibility of this agreement was only possible because the Netherlands East Indies possessed by 1913 a virtual monopoly of production. At least 90 per cent of the world's supply was in their hands, owing to the collapse of private enterprise in Ceylon, South India, and other places. It must not be imagined, however, that this position has been easily reached, as prior to 1913 the industry had many bad periods.

Some of the reasons for the survival of the Java industry when its competitors failed may be briefly mentioned. In the first place, the climate of those parts of Java where *Cinchona* is grown appears to be particularly favourable to its growth, and especially to *ledgeriana*. The light volcanic soils also seem to be very suitable. But apart from this, due credit must be given to the way in which the early Dutch adopted the policy of concentrating on varieties producing bark with a high quinine-content. The industry has also been the subject of unremitting research by the Government Cinchona Plantation at Tjinjeroean, and rigorous control in the selection and breeding of new high-yielding varieties has given planting material of the highest quality. At the same time field

experimental work has been undertaken with the object of overcoming the difficulty of growing *ledgeriana* in old soils and in the introduction of grafting technique and the selection of root-stocks. Work to combat soil losses from erosion by terracing, drainage, and the use of green manures, has been continued, and manurial experiments carried out. These factors, in addition to the economic agreement, have served to place the industry in its present satisfactory position.

C. ledgeriana requires rather special ecological conditions in order to flourish. As regards climate, it will not stand great heat, and frost is fatal. The ideal mean temperature is probably about 75°F. with a mean minimum of 60°F. and mean maximum of 85°F. The limits of rainfall fall between 75 and 150 in. per annum, but the distribution is far more important than the total precipitation. The plant cannot stand long periods of drought and it is therefore found in the East that it is cultivated only in those districts experiencing two monsoons in the year. 'Ledger' also is particular in its soil requirements. Sands [8] mentions that in Java it grows on light loams of volcanic origin of good depth, rich in plant-food, and easily worked. Clay soils are said to be quite unsuited and free drainage is essential. In India it is also found that soils derived from granitic and volcanic formations are the best. They are acid and have a fairly wide range from a pH of 5.23 to 4.58. As regards elevation, *Cinchona* is grown in Java between 3,500 and 6,000 feet above sea level. Below or above these levels the yield is not good. In India the upper limit is 5,000 feet. and the lower about 1,500 feet. At low levels the tree grows rapidly, but has a short life, is liable to disease, and the bark has a low percentage of alkaloid. At the higher levels the growth is slower and the yield of bark is smaller. *C. succirubra* is somewhat less exacting in its requirements both as regards elevation, soil, and rainfall, but the same general conditions apply to it as to *ledgeriana*. It will thus be seen that the plant is exacting in its requirement, and it is natural, therefore, that the number of localities suitable, and the areas of land available, are somewhat limited.

CULTIVATION

In India the sequence of operations is as follows. A suitable area of virgin rain-forest is selected and felled during the cold season (November to March). If steep, this land is terraced and staked 4 × 4 ft. to mark the sites of the young trees, which are planted out from the nursery beds in specially prepared holes, during May, and continuing for the next two months when rainy conditions prevail. In Darjeeling light shade-trees only are needed, but

heavier shade is required in Madras and Burma. Seedlings are raised and used as plants, and although experiments with grafting have been made the practice of planting out seedlings still prevails in India. The soil of the nursery-beds is carefully prepared from leaf-mould collected from the forest. It needs to be worked to a fine consistency, since the seed is very small and light and one ounce will give 20,000 seedlings. It germinates in about three weeks. The nursery-beds are sheltered by sloping roofs of thatch to protect the young seedlings from heavy rain or sun, and seeds are sown in March. They must be carefully watered with a fine spray at regular intervals. The seedlings are transplanted twice, first when the seed leaves are just fully expanded to a distance of 1 in. apart, and later at the age of three months, in May and June, when they are 2 or 3 inches high, and then the spacing is 3×3 in. They are planted out after they have been in the nursery for about two years, and a fortnight before they are transplanted the roofing of thatch is gradually removed to harden off the plant. The young plantation is cleared about twice a year for the first two or three years, but later periodical hoeing round the tree is all that is required. Harvesting of the bark begins about the fourth year when thinnings and prunings are dealt with. The final uprooting is made in the 10th year, as the figures available indicate that a 10-year rotation gives the greatest return in quinine per unit of area. At the final harvest, the whole tree is uprooted, and the bark stripped from roots, stems and branches, which is then dried, stored and passed to the factory. This method is said to give better results than a system of coppicing, which has also been practised.

The system employed in Java differs essentially, as grafted plants are utilized as well as seedlings. The methods employed for raising seedlings are essentially similar to those described above, except that the seed-beds are more elaborate and the times of transplanting somewhat different. The *ledgeriana* plants are all raised from specially selected trees. These are chosen for their strong, healthy growth, erect stem and erect branching habit, size and colour of leaves, thickness of bark, quinine content, age at which first flowers are formed, and resistance to disease. The age at which the tree flowers is important, as early flowering is correlated with loss of vegetative vigour. Strains with reddish levels of medium size are favoured by planters, and trees with an erect branching habit are not so apt to crowd each other as types with a spreading habit. The original trees produced from seed purchased from Ledger, many of which are still living at the age of 60 years, showed considerable variability, particularly in the quinine content, which is stated to range from 3 to 13 per cent. The care which has been exercised over so many years in selecting material with a high

quinine-content for planting, is one of the reasons why the industry has been able to weather so many vicissitudes in the past and is now in its present profitable state.

C. succirubra is grown on a few small estates where the elevation and soil are not so suitable for *ledgeriana*, since it is hardier, more adaptable and possesses a stronger root-system. It is for these reasons grown on all the large estates, not for its bark, but as a root-stock for grafting purposes. Sands gives an interesting account of the method of grafting, and states that the percentage of grafts which grow is usually over 90. The grafted plants are ready for the field in 8 or 12 months after grafting. From the time of planting of *succirubra* seed to the planting of the grafted plant in the field, a period of about three years is necessary. *Ledgeriana* seedlings are usually planted on newly cleared forest land, but it is said to be hard to establish on old land, and as the area of virgin forest that remains is now limited, resort has been had to grafting selected *ledgeriana* material on to *succirubra*.

Progress has also been made in the Belgian Congo in recent years. Stoffels [9] gives a good account of the methods employed in raising seedlings and in grafting *ledgeriana* scion on to *succirubra* stocks, which differ in certain details from those used in Java. It is obvious from this brief account that research has played a vital part in the Java industry from the early days. In a recent report to the Imperial Council of Agricultural Research for India, the need for systematic research on similar lines in India is stressed. In the early days outstanding work was done by McIvor in Southern India and Gammie in Bengal, and much of the *Cinchona* was propagated by vegetative methods on the Government Cinchona Plantations, but in recent years research has played a subordinate part, and the small and inadequate staff has had to concentrate on the work of supplying bark, extracting the alkaloid, and despatching the produce of the factories. The policy has been so to work the departments that they entailed no loss to the State. The Java Reports for 1938 show that the *Cinchona* bark produced in that country worked out at 8 per cent of quinine sulphate, whereas the corresponding figure for India was about 4 per cent. It is recognised that the soil conditions and rainfall distribution are not so favourable in India [10] as they are in Java, but it is believed that a properly organised research station ought to be able to raise the percentage to 7 within a reasonable time. Attempts to graft *ledgeriana* on to *succirubra* stocks in India have met with indifferent success up to the present, but it is suggested that three-quarters of the failure is due to ignorance of

the correct technique. In Java, trained artisans can make over 200 grafts a day with an astonishing degree of success, and there seems little doubt that with perseverance and due encouragement, similar results ought to be obtainable in India.

POSSIBILITIES OF EXTENSION IN THE BRITISH EMPIRE

Too complete a reliance on one country for supplies of this vital product, which might prove dangerous in times of war, have recently caused another enquiry to be held into the possibility of extending the cultivation of *Cinchona* within the borders of the Empire. This has shown that the areas with the exacting conditions of climate and soil suited to its growth are definitely limited, but it will be of value to record the progress that has been made in recent years to establish or extend new plantings.

India and Burma.—In India the present position is that the possibility of extending in Bengal is very limited, whilst in Madras new areas are being tried out in the Anaimalais, and a recent report by Wilson and Mirchandani [11] indicated that enough first-class land existed for an early resumption of *Cinchona*-growing, about 38,000 acres of first-class land being available in Bengal, Assam, Orissa, Bhutan, Sikkim, Madras, Mysore, and Coorg. The production of *Cinchona* by planters has now practically ceased. The old plantings in the Darjeeling district have long ago been replaced by tea and those in Southern India have been grubbed up and abandoned or replaced by coffee or some other crop. Further recent attempts to interest the planting community in this crop have not proved successful. A manifesto addressed to the Government of Madras by the Planters' Association, as lately as August, 1938, laid down the following conditions as essential to any such project:—

1. A guarantee to absorb the production from *Cinchona* estates, provided the bark is of good quality.
2. A guarantee to pay the market rates subject to a fixed minimum.
3. Partial remission of land assessment on areas planted in *Cinchona* for a certain period.
4. The planters to guarantee not to sell their bark to anybody except the Government.
5. Government to have the right to limit the areas to be planted.

The matter of a guaranteed minimum price had been the subject of repeated representations from 1895 onwards, and finally in 1925 the Government refused. Accordingly, after an agreement with the Planters' Association, new lands in the Anaimalai Hills were opened up by Government in 1925 in order to supplement the supply of bark from the Nilgiri plantations. These new plantations appear to be doing well and unlike other areas in South India, the *ledgeriana* species seems to be doing better. There the matter rests at present.

Practically all the quinine now produced in India is grown and manufactured by Government, but this is only sufficient to meet one-third of the annual consumption, the rest being purchased from Java. It seems improbable that private enterprise will undertake *Cinchona*-planting unless a guaranteed minimum price is forthcoming, and the alternative to continued dependence on Java is for the Government to expand its own plantations.

Attempts to establish *Cinchona* plantations in Burma were made following the report of Lt.-Col. A. T. Gage,[12] who was commissioned to inquire into the possibility of increasing *Cinchona*-planting in the Indian Empire, under instructions from the Government of India. In this report the suggestion was made that the hill ranges of Tavoy could probably furnish all the quinine needed by the British Empire, and also that the proposed plantations should come under the direct control of the State. Work establishing in the new plantations was started in 1920, but those in Tavoy were destroyed in heavy rains in 1921 and 1922. Accordingly, a new site was chosen in Mergui district in 1923. This also was not a success, because of the low elevation and the abnormally long dry season. Difficulty was also experienced with labour. This plantation was closed down in April 1937, when under the new constitution Burma became separated from India, and she refused to assume the financial responsibilities involved. There are many who remain convinced that there are considerable possibilities for *Cinchona* in Tavoy, particularly in the ranges farther inland from the coast where the rainfall is not so torrential.

East Africa.—It has already been shown that trials of *Cinchona* were made in earlier years at a number of places where it was considered that conditions offered a reasonable chance of success. Many of these experiments failed, but in one or two colonies, such as Ceylon and Jamaica, better results were obtained and a considerable industry was built up, only to collapse during the period of over-production in the 'eighties. In the post-war period the unsatisfactory position of Empire-grown supplies was considered by the Imperial Government. In 1925 the Committee of Civil Research

appointed a sub-committee to enquire into Empire supplies and reported that any scheme for extension would be premature, pending further information about synthetic products, but that in any event it would probably be necessary to create new plantations if the Empire was to be self-supporting in quinine and *Cinchona* alkaloids. As a first step, a grant of £2,000 a year was made to Amani in Tanganiyka to enable that research station to carry out experimental work and restore the old plantations. It must be remembered that the Germans had imported seed of *ledgeriana*, *succirubra*, and the hybrid from Java, as early as 1901 and had established plantations and a factory at Amani for the production of quinine. These plantations were all cut down during the East African campaign, and the quinine so produced was an important factor in preserving the health of their forces. The old plantations had coppiced or ratooned freely, and the grant was utilised not only to regenerate the old German plantation, but also to plant new areas. Following a progress report in 1930, a sub-committee of the Colonial Advisory Council of Agriculture was appointed in 1931, and it advised against any further work, mainly on the grounds that the use of quinine as a specific for malaria was likely to be displaced by more efficient synthetic products. As a result, all the *Cinchona* trees at Amani were cut down and the bark stripped, except a plot of *C. ledgeriana* which was kept for seed. An interesting account of *Cinchona* in Amani at the present time is given by Worsley [13] together with analyses of the different kinds of bark and costs of production. It is noted that at Amani, as elsewhere, *ledgeriana* produces less bark than *succirubra*, but gives higher quinine percentages, which were on the whole satisfactory. In 1936, following representations made by certain Colonial Governments, the quinine position was again reviewed by the Colonial Agricultural Advisory Council, and as a result *Cinchona* research is now included in the programme of the Amani Institute. The most recent reports show that in addition to the plantations controlled by the Institute, there are about a dozen privately owned plantations in the Usambara Mountains, which have areas of old plantings as well as young trees. Research at Amani indicates that the soils are patchy and that the best areas are situated in the wetter parts of the Western Usambara Range, where the rainfall is heavier and better distributed. Young *ledgeriana*, when grown in suitable situations and on the right type of soil, is showing considerable promise. The work so far carried out indicates that there is much to be learnt, since the methods of cultivation employed in India or Java cannot be adopted wholesale in this part of Africa. As an instance, trees growing under shade are promising, whereas this practice is not the rule in India. Further, the old *Cinchona* trees at Amani have regenerated surprisingly

well from coppicing, which is not the case in other *Cinchona*-growing countries, where the trees after they have reached the age of eight years or so are grubbed up, barked, and replanted with young trees. Whether coppicing will prove the best practice in the long run remains to be seen. Investigations are also being conducted into the control of the *Armillaria* root disease, which, together with *Helopellis*, causes some loss. In the meantime, the Amani nurseries are supplying seedlings to the private planters in the area. The varieties issued consist chiefly of *ledgeriana* and its hybrid, together with *succirubra*, which seems to grow particularly well and possesses a fair quinine-content. The question of establishing a factory depends on whether the consumption of quinine in East Africa would justify the cost.

West Africa.—Experiments are being conducted in the Mandated Territory of the Cameroons. As in Tanganiyka, *Cinchona* was first introduced by the Germans about thirty years ago, and three small plantations were established, two being near Buea at altitudes of 3,200 and 3,500 feet, and another higher up the mountain at Musaka (5,600 feet). Many trees were cut down during and after the war and no further interest was taken until 1923, when these areas were surveyed, new seedlings planted, and 1,047 trees counted. By 1927 the number of living trees had been reduced to 521. The old trees were found to have coppiced quite well in some places, and the proportion of trees still alive was considered satisfactory in view of the years of neglect that had elapsed. The soils are of volcanic origin and the rainfall conditions appear to be favourable. Recent work has led to the conclusion that *succirubra* is more suited to conditions than *ledgeriana*, which is giving disappointing results when grown on its own roots. As it was thought that the only hope of establishing an industry was to produce ledger bark, selection work on this species was commenced in 1937, and 23 of the most promising trees were selected for vegetative propagation. Care is being taken to preserve these trees by manuring, as some of them are in a bad way, owing to long years of neglect. Meanwhile investigations to inquire into the possibility of budding or grafting on to *succirubra* stocks were started in 1939. Budding was found to be impracticable, but grafting was more successful. It has been found that by using young, vigorously growing twigs, which were only slightly woody, and had a soft pliable, light-coloured bark, a fair percentage of successful grafts could be made. By the end of 1939, 1,140 grafts had been made and 43 per cent were successful, dealing with 12 clones. More success was obtained with some of the clones than others, but this is probably

due to the actual condition of the parent tree. In the meantime, the supply of *succirubra* stocks is being increased, and it should be possible by the end of 1940 to supply small quantities of grafted plants for experimental planting on estates. Further progress will depend on the manner in which these plants flourish and the price of bark and other economic factors.

Malaya.—Much work has been done in recent years at the Agricultural Station in the Cameroon Highlands. Here excellent growth has been made by both *C. succirubra* and the hybrid seedlings, but seedlings of *C. ledgeriana* are slow in growth and lack vigour. On the older areas this species was also in an unhealthy condition, being attacked at the base of the stem by the parasite *Phytophthora cinnamoni*, which is associated with weak, unhealthy trees. Experiments made here also seem to indicate that *ledgeriana* growing on its own roots is not likely to be successful, and steps are now being taken to graft it on to *succirubra* seedlings, which grows much better under local conditions.

New Guinea.—Trials with four kinds of *Cinchona* have been made at the newly established Agricultural Station at Aiyura which is situated at about 6,000 feet on the divide between the headwaters of the Ramu and Markham rivers. Although these trials are still in their early stage, growth is satisfactory and soil and climate are said to be suitable for *ledgeriana*.[14]

Ceylon.—Interest has again revived in *Cinchona*, and a recent report by Haigh [15] expresses the opinion that Ceylon has a reasonable chance of producing quinine more cheaply than she can buy it. Preliminary trials have been made and seed-beds planted at Malpota. A survey of suitable areas between 3,000 and 5,000 feet has been made, and it is proposed to plant one-acre test plots on nine representative areas as a preliminary step. Budding and grafting trials are also being carried out with the object of determining the most suitable technique.

SUMMARY

In conclusion, it is important to remember the factors that are necessary to establish a *Cinchona* industry. They are not only concerned with the successful production of bark. As indicated in this note, there is probably sufficient suitable area in the Empire to provide all the quinine it requires. It has been estimated that India alone possesses 38,000 acres of first-class land for this purpose, and there are other large potential areas scattered throughout the Empire, in many of which experiments are now being conducted with promising results. The costs of production have proved

difficult to estimate, but in Bengal it may be assumed to be around Rs. 10 per lb. (the rupee = 1s. 6d.) But the experience of the Cinchona Departments of India indicates that the difficulty was chiefly that of distribution. Production is one thing — consumption is another. Given the necessary financial backing and an organised official drive against malaria, much could be accomplished. Lacking these preliminaries, success for a planting industry would appear to be problematical. It must be remembered that the Kina Bureau controls the quinine market, and, as has already been pointed out, it is regulating production from the Java plantations, which can readily expand their output to a very considerable extent, should the necessity arise.

The desire to render the Empire less dependent on outside sources for supplies of this essential specific is natural, but if production is to be increased, it will either have to be done by the establishment of *Cinchona* plantations and factories by the Government, as in India, or by private enterprise. If the latter is to be encouraged, the need will arise to consider State assistance in the shape of a guaranteed minimum price for bark over a period of years, to be accompanied by an organised drive to popularise the use of quinine, and the establishment of an adequate system of distribution.

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HOUSING OF ESTATE LABOUR*

B. D. FAY

The problem of finding suitable sites on steep up-country estates on which to build extra line accommodation, where necessary, for one's present labour must have exercised the minds of numerous Superintendents.

Apart from the undesirability of cutting out valuable tea, when estates have no suitable wasteland on which to build, the lack of sufficient water, particularly in Uva, may make it impossible to find any site that will meet the demand, so the only alternative to my mind is to build up. This can be done by converting existing single line room sets into two storey buildings which will amplify an estate's line accommodation for its present labour force up to 100 per cent of its existing single line rooms, thus eliminating the necessity of finding new sites or fresh water supplies.

A sketch of the plan I have in mind with details of construction is shewn overleaf, from which it will be seen that an existing ground floor room is to be extended to include the verandah thus giving a room 10 feet × 19 feet or 12 feet × 17 feet, preferably the former, to reduce the ceiling span. Above this a room 10 feet × 12 feet is constructed and the balance of the space is utilized for a verandah exactly over and equivalent in dimensions to the original ground floor verandah. Access to the upper floor is given by an inside staircase from the lower enlarged room thus providing two intercommunicating rooms, ideal for large families. A suitable kitchen could be erected along the back of the building, to complete the ensemble.

* The Institute does not necessarily endorse the views expressed in papers contributed by others than members of the staff.

The above arrangement doubles one's single room line accommodation without increasing sites, water or roofing requirements, the latter being of vital consideration in these days of expensive roofing materials.

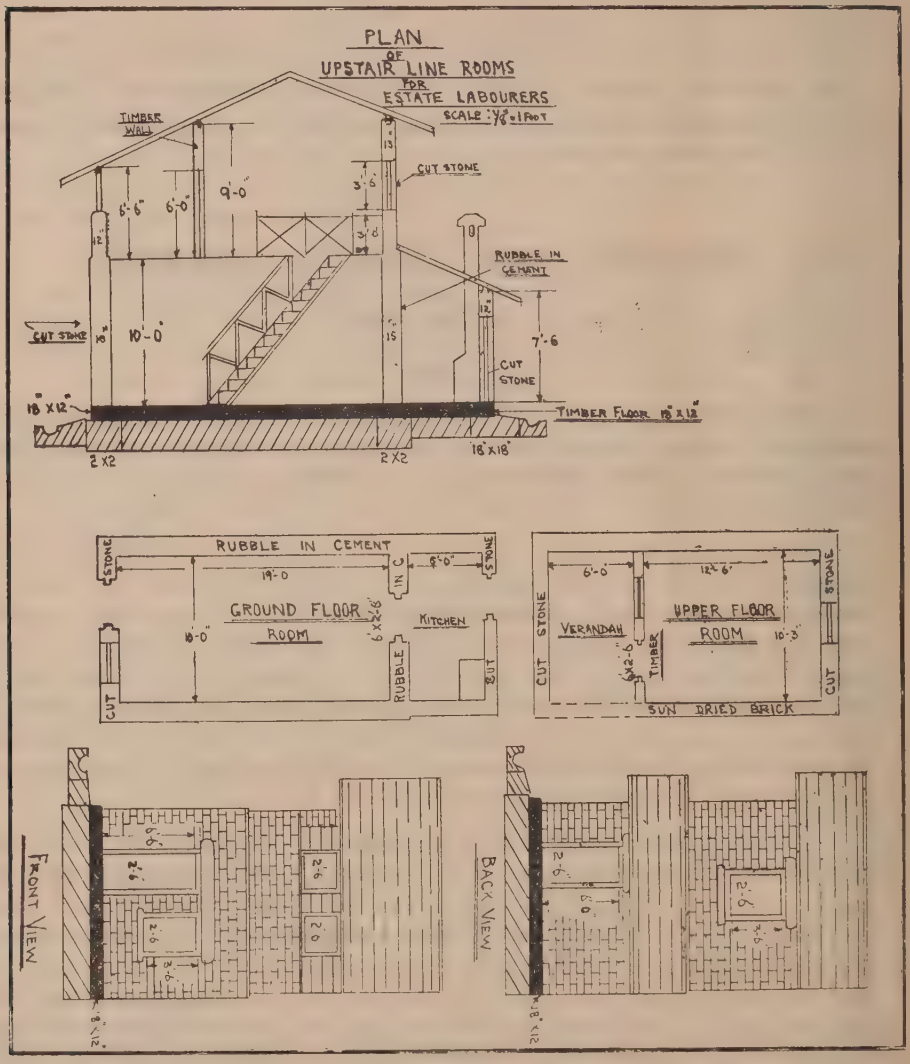

Fig. 1

This suggestion has been laid before the Inspecting Medical Officer and the Director of Medical and Sanitary Services both of whom have no objection to the arrangement, and any of my labour to whom I have spoken are enthusiastic about it. The plan shown in Fig. I has since been approved for this estate by the Director of Medical and Sanitary Services.

MINUTES OF A MEETING OF THE BOARD OF THE TEA RESEARCH INSTITUTE OF CEYLON HELD 6-11-41

Minutes of a Meeting of the Board of the Tea Research Institute of Ceylon, held at the Ceylon Chamber of Commerce Rooms, Colombo, on Thursday, 6th November, 1941, at 3 p.m.

Present.—Adigar T. B. Panabokke (Chairman), the Hon'ble the Financial Secretary (Mr. H. J. Huxham), the Director of Agriculture (Mr. Edmund Rodrigo, C.C.S.), the Chairman, Ceylon Estates Proprietary Association (Mr. C. H. Bois), Messrs. R. G. Coombe, J. D. Hoare, J. C. Kelly, W. H. Gourlay and Dr. R. V. Norris (Director and Secretary).

1. The Notice convening the meeting was read.

2. The Minutes of the Meeting of the Board held on the 24th July, 1941 were confirmed.

Tabled letter from Chairman, Planters' Association of Ceylon (Mr. D. E. Hamilton), regretting inability to be present.

3. MEMBERSHIP OF THE BOARD AND COMMITTEES

(i). Reported that Mr. J. C. Kelly had returned from leave and resumed his place on the Board and Finance Committee

The Chairman welcomed Mr. Kelly and asked the Board to record their thanks to Mr. R. P. Gaddum for his services while acting for Mr. Kelly.

(ii). Reported that Mr. S. F. H. Perera's nomination as the representative on the Board of the Low-Country Products Association had expired on the 25th September. A new nomination by the Low-Country Products Association was awaited.

4. FINANCE

Institute's Accounts to 30th September, 1941.—The Chairman said the position was favourable due to good cropping and high tea sales, though receipts from the cess were still below the estimate due to delay in tea shipments.

The Chairman reported that the payments due in September on account of interest charges and capital repayments of the Government Loan had been duly met.

Cash Position.—The Chairman said Rs. 32,000 was on fixed deposit. This included Rs. 25,000 against loan payments due in 1942. The latter sum might be increased at the discretion of himself and the Director as funds permitted. The balance on current account at Rs. 61,038 was somewhat high but the payments against factory alterations, etc. had still to be met.

(ii). *Subscriptions to War Charities.*—The Chairman referred to the appeal for the Merchant Services Comfort Fund and asked if a donation could not be made to this deserving cause. It was decided however, in view of the Attorney-General's ruling that the Institute could not contribute to such Funds.

(iii). *Estimates 1942.*—It was decided for estimating purposes to take the exportable quota for the restriction year 1941-42 at 87 per cent of the standard crop.

5. ST. COOMBS ESTATE

Visiting Agent's Report dated 28th October, 1941.—The Chairman said this report had only been received a few days ago and would be considered by the Estate and Experimental Sub-Committee on the 29th November. Meantime he invited comments.

(1). *Labour.*—The Chairman said there had been some difficulty in keeping up-to-date with routine work owing to the large amount of male labour required in connection with the factory alterations and other work on Capital Account.

(2). *Crop.*—It was reported that the estimate would probably be exceeded in spite of somewhat unfavourable weather since the monsoon began.

(3). *Soil Erosion.*—The proposals on page 3 of the Visiting Agent's Report would be put before the Experimental Sub-Committee.

(4) *Manures.*—Reported that the Director and Agricultural Chemist were in favour of a reduction in the amount of phosphoric acid in the estate mixture and proposals to this effect would be submitted to the Experimental and Estate Sub-Committee.

(5). *Nurseries.*—In reply to Mr. Coombe the Director said he thought the chief trouble was drainage. The matter was being considered by the Agricultural Chemist.

(6). *Upkeep and Cultivation.*—Page 5 of Visiting Agent's Report. These proposals would be referred to the Experimental Committee.

Mr. Hoare suggested that the real cost of certain items of work could be more clearly shown if this were given in cost per acre instead of cents per pound of tea. The Director said in the monthly statements it was necessary to adhere to one system. He agreed, however, that in the estimates and reports cost per acre of appropriate items could be shown and he would take up this matter.

(7). *Factory Extension and Alterations.*—The Director reported the progress made in the above works which he hoped would be complete about the end of the month.

(8). *Water Borne Sanitation.*—The Director said work was in progress installing water borne sanitation. He had been struck by what appeared to him the excessive size of the disposal part of the system and he thought the working of the system should be observed before further lines were converted.

Mr. Kelly pointed out that the Medical Authorities were responsible for this part of the plan.

After discussion it was decided (i) that the Government Medical Inspecting Officer might be asked to comment on the plan, (ii) that Dr. Svensson should be asked to inspect the system when in working order, and (iii) that provision for converting further lines should be deferred until his views had been ascertained.

(9). *Weeds and Ground Covers.*—Mr. Hoare referred to the comment of the Visiting Agent in connection with weeds in relation to ground covers and asked that this might be looked into. He also asked for information in regard to the rotation of shade trees and green manures.

The Director said in regard to shade trees it was desirable to arrange for regular replacement so that a stand of vigorous trees of suitable size might be maintained. In regard to green manures it was necessary to have a rotation to reduce the risk of heavy soil infection with pests such as eelworm, etc.

In reply to Mr. Gourlay, the Director said Gliricidias did not do well on St. Coombs which was probably too high for it. In reply to Mr. Coombe, Dr. Norris said he had no objection to Acacia.

(10). *Food Production.*—The Financial Secretary said he noted no provision seemed to exist for food production and asked what the position was. He thought most strongly the Institute should continue work on food production.

The Director said the only land available at St. Coombs for food production was patana and referred to the Annual Report for 1940 in which the results of the Institute's trials were given. It would be seen that these had been a complete failure though everything had been done to bring the area into good cultivation. He appreciated the importance of the subject but considered the land in question was quite unsuitable and further trials would only be a waste of money.

Mr. Hoare said the fact that chena cultivation was not carried out on the Uva patanas supported the view that patana land was unsuitable for production of the crops desired.

In reply to Mr. Gourlay who asked as to the possibilities of producing crops, such as Indian corn, interplanted with tea, the Director said he did not consider this had any chance of success.

The Director of Agriculture said his Department had not experimented with patana land. He supported the Director however in his view that further trials at St. Coombs would be of little value. After further discussion the Financial Secretary said he would not press the matter further.

Mr. Coombe reminded the Director of the suggestion that Members of the Experimental Committee should have an opportunity to see the clearings, etc., before the next meeting. The Director said he would try to arrange this.

6. JUNIOR SCIENTIFIC STAFF

(i). Reported that Mr. B. T. Schuiling, Field Assistant, Passara, had resigned his appointment as from 31st October and his resignation had been accepted by the Director.

It was not proposed to fill the vacancy immediately but to consider this when the question of research for the Low-country came up for discussion.

7. RESEARCH FOR THE LOW-COUNTRY

Reported that a circular had been issued to Low-Country Planters' Associations on this subject and the Director had arranged to meet the Associations concerned to discuss the question. A memorandum would then be prepared for submission to the Experimental Committee.

8. FACILITIES FOR TRAINING CEYLONESE STUDENTS AT ST. COOMBS

The Director reported that this subject had been discussed at the last meeting of the Board of Agriculture held on the 4th November. In accordance with the instructions of the Board he had intimated that while the Board agreed in principle to the provision of facilities for training in research methods it was considered training in estate management could only be given on commercial estates. The Directors of the Rubber and Coconut Schemes had taken a similar line.

A resolution that training in research and estate management should be provided for Ceylonese graduates had been passed by 3 votes to 1. The further resolution that such training should be given at the three Research Institutes had been defeated by 8 votes to 2.

9. ST. COOMBS CADDAI

The Board approved the fixing of the Institute's seal to a new agreement rendered necessary by a change of the proprietorship of the caddai.

10. ANY OTHER BUSINESS

(i). *Research in the Chemistry of Tea.*—The Director reported that a further technical report had been received from Dr. Bradfield. Encouraging progress was being made.

(ii). *Next Board Meeting.*—It was decided that the next meeting of the Board should be held in Colombo on Thursday, 18th December, a meeting of the Finance Committee being held in the morning of the same day.

The Meeting then concluded with a vote of thanks to the Chair.

ROLAND V. NORRIS,
Secretary.

NOTICES.

The Institute's Laboratories and Offices are situated at St. Coombs, Talawakelle, and all applications and enquiries should be addressed to the Director, Tea Research Institute, St. Coombs, Talawakelle.

Specimens and other consignments sent by rail should be forwarded to Talawakelle Station c/o Messrs. M. Y. Hemachandra & Co., Forwarding Agents. *Carriage should be pre-paid.*

Visitors' Days.—The *second* and *last* Wednesdays in each month have been set aside as Visitors' Days at St. Coombs Estate, and also at the T. R I. Sub-Station, Gonakelle Estate, Passara, when it is hoped anyone interested will visit the Stations.

Visitors at other times are welcomed, but it is requested that an appointment be made if possible.

RULES FOR THE OCCUPATION OF ST. COOMBS GUEST HOUSE

(1). The Guest House is normally intended for the use of persons visiting the Institute and St. Coombs Estate on business. Children can in no circumstances be accommodated.

(2). Permission to occupy a room for the night must be obtained from the Director in writing and, unless sufficient notice be given, accommodation cannot be guaranteed. Two double rooms are available for the use of visitors accompanied by their wives.

(3). All visitors must sign the Visitors' Book on arrival.

(4). A bedroom may not be occupied for more than one night if required by another visitor. This shall not apply to Members of the Board or of Committees meeting at St. Coombs who shall also be entitled to priority in the allocation of accommodation when on official business

(5). Complaints or suggestions shall be entered in the book provided for the purpose and not made to the Guest House Staff. All payments due for services rendered shall be made in *cash* to the steward-in-charge and a receipt obtained from him on the official form. The scale of approved charges is posted in the building. The steward is forbidden to give credit or to accept cheques.

(6). Liquor is supplied for consumption *in the premises only*.

(7). The Institute accepts no responsibility for cash, jewellery or other valuables of any kind left in the Guest House.

(8). All breakages will be charged for at cost price.

ROLAND V. NORRIS,
Director.

The Tea Research Institute of Ceylon.

BOARD OF CONTROL

(A) Representing the Planters' Association of Ceylon:—

(1) Mr. R. G. Coombe

(2) Mr. James Forbes (on leave), Mr. G. K. Newton (acting)

(3) Mr. J. D. Hoare

(B) Representing the Ceylon Estates Proprietary Association:—

(4) Major J. W. Oldfield, C.M.G., O.B.E., M.C.

(5) Mr. I. L. Cameron (on leave) Mr. W. H. Gourlay (acting)

(6) Mr. J. C. Kelly

(C) Representing the Low-Country Products' Association:—

(7) Mr. W. P. H. Dias

(D) Representing the Small-Holders:—

(8) Mr. T. B. Panabokke, First Adigar (Chairman)

(E) Ex-Officio Members:—

(9) The Hon. the Financial Secretary

(10) The Director of Agriculture

(11) The Chairman, Planters' Association of Ceylon

(12) The Chairman, Ceylon Estates Proprietary Association

Secretary, Roland V. Norris, D.Sc., St. Coombs, Talawakelle.

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The publications of the Tea Research Institute will be sent, free of charge, to Superintendents of Ceylon tea estates, over 10 acres in extent, and to Estate Agencies dealing with Ceylon tea, if they register their names and addresses with *the Director, Tea Research Institute of Ceylon, St. Coombs, Talawakelle.*

Other persons can obtain the publications of the Institute on application to the Director, the subscription being Rupees fifteen per annum for persons resident in Ceylon or India, and £1-5-0 for those resident elsewhere. Single numbers of *The Tea Quarterly* can be obtained for Rs. 2·50 or 4*s*. In the case of Indian cheques four annas should be added to cover commission.